perimental evidence adduced in support of this view consisted chiefly of the observation which he made that the parent nitro-paraffin was not, or only to a slight extent, regenerated upon treating the sodium compound with dilute sulphuric acid, the compound being decomposed with evolution of nitrous oxide and formation of an aldehyde or ketone. Prof. Meyer has made further experiments in this direction, and their results definitely fix the nature of these sodium compounds, proving that they are indeed true sodium derivatives of the nitro-paraffins, being formed by the replacement of one of the hydrogen atoms of the alkyl radicle by sodium. It is a fact that when sodium nitro-ethane, $C_2H_4NaNO_2$, is dissolved in excess of dilute sulphuric acid at the ordinary temperature, a somewhat vigorous evolution of nitrous oxide occurs. But if the most elementary precautions are taken to prevent the decomposition of so unstable a substance by the thermal change involved in so energetic a reaction, the decomposition proceeds quite differently. If the sodium compound is first dissolved in a little water well cooled by ice, and then an equivalent added of dilute sulphuric acid similarly cooled to near 0°, only a very few bubbles of gas escape, and barely a trace of the odour of aldehyde is perceptible, while a layer of oil, consisting of nitro-ethane, separates out. Even after the operations of purification, which involve some loss owing to the volatility of nitro-ethane, over 60 per cent. of the theoretical quantity of the pure nitro-paraffin was isolated. Moreover, the small quantity of decomposition indicated by the few bubbles of nitrous oxide can be entirely avoided by employing acetic instead of sulphuric acid; the reaction is then less vigorous, and consequently produces at temperatures not far above 0° no dissociation of the nitro-paraffin. The observation of Nef, that the sodium derivatives of the nitro-paraffins are decomposed at the ordinary temperature by the stronger acids, even when diluted, into nitrous oxide and an aldehyde or ketone, is an interesting one; but Prof. Meyer's work now shows that this is due merely to the fact that the nitro-paraffin first regenerated is decomposed in all probability by the heat of the reaction between the sodium and acid, and that when the precaution is taken to prevent this rise of temperature by reacting with ice-cold solutions, the regenerated nitro-paraffin remains intact. Hence it must be concluded that the sodium compounds are true derivatives of the nitro-paraffins which can thus be regenerated from them.

The additions to the Zoological Society's Gardens during the past week include a Vervet Monkey (*Cercopithecus lalandii*, ♀) from South Africa, presented by Captain Scarlett Vale; a Macaque Monkey (*Macacus cynomolgus*, ♂) from India, presented by Miss K. Fleming; a Vulpine Phalanger (*Phalangista vulpina*) from Australia, presented by Mr. Richmond Allen; a Grey Ichneumon (*Herpestes griseus*) from India, presented by Mrs. Lewis; fifteen —— Rats (*Mus*, sp. inc.) from Sunday Island, Kermadee Group, presented by the Countess of Glasgow; a Hooded Finch (*Spermestes cucullata*) from West Africa, a Chestnut-eared Finch (*Amadina castanotis*) from Australia, presented by Mr. C. H. Hastings; a Woodcock (*Scolopax rusticula*), British, presented by Mr. Charles Smoothy; a Long-necked Chelodine (*Chelodina longicollis*) from Australia, deposited; four Marbled Newts (*Molge marmorata*), European, purchased.

OUR ASTRONOMICAL COLUMN.

Partial Eclipse of the Sun, March 26.—On March 26 a small partial eclipse of the sun will, if the weather be favourable, be seen from all parts of the British Isles, with the probable exception of places which are to the east of a line joining Lowestoft and Hastings. At Greenwich the magnitude of the eclipse, sun's diameter = 1, will be 0·013, and the first contact will occur at 9.56 a.m., with a duration of only 27 minutes. At Oxford the magnitude will be 0·03, and the duration 40 minutes. At Dublin the magnitude will be 0·09, with a duration of 67 minutes, and at Edinburgh 0·08, with a duration of 62 minutes. The eclipsed part will be a maximum (0·36) as seen from the north-east of North America.

In the *Nautical Almanac* for the current year the eclipse is said to be *invisible* at Greenwich, but the error was corrected in the *Almanac* for 1897. The mistake, however, has not been corrected in many of the almanacs in common use.

Distribution of Minor Planets.—An interesting diagram has been constructed by General Parmentier, to show the distribution of the minor planets at present known between the orbits of Mars and Jupiter (*Bulletin Soc. Ast. de France*, March). Of the 390 planets for which sufficient data are available, 93 have a mean distance between 2·16 and 2·48; 152 between 2·52 and 2·82; 128 between 2·85 and 3·25; and 10 between 3·38 and 3·48. The interval between Brucia (at 2·16) and Mars, is occupied by a single asteroid, comparatively recently discovered, with a mean distance of 2·09. On the outer side of the dense swarm, there are only six minor planets in a zone very nearly as wide as that occupied by the group of 383, and extending to a mean distance 4·68. The region of greatest density of the asteroids so far discovered is at a mean distance from the sun very nearly equal to that indicated by Bode's law (2·80); Ceres, Pallas, and Juno fall a little short of this distance.

At the present rapid rate of discovery of minor planets by the photographic method, data will no doubt soon be available to determine if the outer zone between Camilla and Jupiter is really an almost deserted region.

The Royal Observatory, Edinburgh.—We are glad to hear that the new National Observatory for Scotland is making rapid progress towards completion. The buildings are quite finished so far as the outside is concerned, and it is hoped that the two equatorials and the transit instrument will be erected in the early summer. The library will be ready to receive the magnificent collection of twenty thousand volumes as soon as the heating arrangements are completed.

PHYSICAL WORK OF HERMANN VON HELMHOLTZ.[1]

II

König has shown that in many cases, when two notes are sounded simultaneously, beats are heard, as though the most prominent phenomenon was the production of beats not between the two fundamental notes, but between the upper of these, and the nearest partial of the lower note. Inasmuch as these beats are heard when the lower note (as far as can be tested) is free from upper partials, this rule is not the explanation of the phenomenon, but it is a convenient way of expressing the results. In the experiment just described, the frequencies of the two notes were in the ratio 12 to 15. The first partial of the lower note (12) is therefore the nearest to the higher tone; that is to say, König's beat tone and the first difference tone are identical.

It is easy to arrange an experiment in which these conditions are not fulfilled. Thus let the notes be in the ratio 9 : 15. The second partial of the lower note is 18, which is nearer to 15 than to 9; hence the König beat-tone would have a relative frequency of $18 - 15 = 3$. If the siren rotates 10·6 times per second, the frequencies of the two fundamental notes are $9 \times 10{\cdot}6 = 96$ and $15 \times 10{\cdot}6 = 160$ respectively. As before, the difference tone is 64.

In this case we can use another method of determining the speed of the siren. In 1880 Lord Rayleigh constructed an instrument in which the mass of air enclosed in a tube is excited by resonance, and the fact of the excitation is indicated by a light mirror, which is set where the motion is greatest, inclined at 45° to the direction of the air-currents. In accordance with the general law that a lamina tends to place itself perpendicular to the direction of a stream, the mirror moves when the air vibrates. In the original apparatus the amount of the movement was controlled by magnets. Since that date Prof. Boys has modified the instrument by substituting a quartz thread suspension for a silk fibre, and using the torsion of the thread instead of the directing force of the magnets. In a lecture delivered before the British Association, in Leeds, he exhibited the apparatus, which is sometimes called a mirror resonator. Prof. Boys has been good enough to make two of these instruments for me, and for reasons, which I will not at the moment enter into, we decided that one of them should respond to 161 vibrations per second. It so happens that this coincides almost exactly with the frequency of one of the notes in the experiment under discussion (160). It is thus possible to use the mirror resonator as an auxiliary instrument to test the speed of the siren. When the proper note is reached the spot of light will move, and if the difference tone is objective the interference bands ought to disappear simultaneously. We tried this experiment several times. An observer, so placed that he could not see the interference bands, lifted his hand when the spot of light moved. It was quite extraordinary to note the absolute agreement between his movements and the behaviour of the bands.

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[1] A discourse delivered at the Royal Institution, by Prof. A. W. Rücker, F.R.S., on Friday, March 8. (Continued from page 475.)

By throwing the spot of light and the bands near together on the screen, the coincidences can be watched by a number of persons. We have tried whether the difference tone is objective in four cases, and in all have detected it by the disappearance of the interference bands. The details of the experiments are collected in the following table. In the first two experiments the first difference tone is, and in the last two it is not, coincident with König's lower beat note.

Difference Tones.

Number of holes in siren.	Interval.	Frequencies.		Difference—and König's beat-tones.	
15 and 12	Major third	320	256	64	64
16 ,, 12	Fourth	256	192	64	64
15 ,, 9	Major sixth	160	96	64	32
18 ,, 8	An octave and a major tone	115·2	51·2	64	12·8

Of course the question at once arises, whether, when it can be distinguished separately, König's beat tone is also objective. I do not wish to express a final opinion on this point, but I may say that when the rows of eight and eighteen holes were opened the speed of the siren was increased till the notes corresponding to 256 and 576 vibrations were produced. König's note would in that case have a frequency of 576 − 2 × 256 = 64. We tried twice to obtain this. On the second occasion, especially, all the conditions were favourable, and the experiment was carried on for a long time. On neither occasion did we obtain the smallest sign of an effect on the fork and interference bands.

We must next turn to the summation tone which Helmholtz discovered. It has been almost universally denied that this note is objective. Without going into details, it is only necessary to remark that the late Mr. Ellis, the translator of the "Tonempfindungen," who took a dispassionate view of the controversy, thought that the position assumed by Helmholtz had been disproved. To the statement of Helmholtz that "it was formerly believed that the combinational tones were purely subjective and were produced in the ear itself," Ellis appended the note: "the result of Mr. Bosanquet's and Prof. Preyer's quite recent experiments is to show that they are so."

In an experiment on the summation tone, as the total number of vibrations must not exceed 64, the notes will be too low to be well heard. I shall therefore use a third method of determining the rate of speed of the siren. A mirror attached to the lower plate of the instrument rotates with it. Concentric with, and lying on this, is a circle of paper with eighteen cogs. Light reflected from the mirror passes through holes in two pieces of tinfoil attached to the prongs of a tuning-fork. When the fork is at rest, these holes are superposed; but when the fork vibrates, they move apart, are closed by the tinfoil, and only cross each other twice in each complete vibration. The tuning-fork makes 27·2 vibrations per second, and thus allows the light to pass 54·4 times per second. But when the siren makes 3·048 revolutions per second, the rows of nine and twelve holes give a summation tone of 64 vibrations, and each cog moves over 18 × 3·048 = 54·9, or say 55 times the distance between two consecutive cogs. If the wheel were viewed 55 times a second, the cogs would appear stationary, as in that interval each would be replaced by the next. As they are really seen about 54·4 times a second, they appear to move slowly forwards at the rate of about one interspace in two seconds. When this speed is attained the bands disappear, thus proving the objective existence of the summation tone.

We have repeated this observation in various ways, and always with success. The results are summed up in the table.

Summation Tones.

Numbers of holes in siren.	Interval.	Frequencies.		Sum.
10 and 8	Major third	35·$\dot{5}$	28·$\dot{4}$	64
12 ,, 9	Fourth	36·57	27·43	64
16 ,, 9	Minor seventh	40·96	23·04	64

It is, perhaps, a drawback that all the notes in these experiments are very low. In order to remedy this, and also to put the matter to the test by means of another instrument, we have employed a mirror resonator, which responds to 576 vibrations per second.

The rows of 15 and 12 holes being opened, notes of 320 and 256 vibrations were produced. When they were sounded separately, the noise seemed just to make the resonator move. When they were sounded together, the spot of light was driven off the scale, when the upper note coincided with that of a 320-vibration fork, but immediately returned when this pitch was lost.

The summation tone of 576 vibrations was also obtained by two other combinations of holes. The 320-fork was used, and the disturbance occurred in the one case when the pitch of the upper note given by the siren was nearly the same as before, and in the other case when it was about a tone higher.

The results are summed up in the table.

Summation Tones.

Numbers of holes in siren.	Interval.	Frequencies.		Sum.
15 and 12	Major third	320	256	576
16 ,, 12	Fourth	329·15	246·85	576
16 ,, 9	Major sixth	360	216	576

I venture to think that these experiments prove the accuracy of von Helmholtz. They show that the siren, at all events, does produce objective tones, the frequencies of which coincide with those of the first difference and summation tones, and that this statement is valid as regards the difference tone, whether it is or is not coincident with König's beat-tone.

I have now in one single case tried to convey to you some idea of the complexity of the problems with which von Helmholtz dealt. He was the first man who detected a relation between the surging mass of partials and combination tones and our sensations of concord and discord. The main facts of his theory are, I believe, generally accepted. On some points modern opinion has tended to stray from his views; one of these we have studied afresh this evening.

It was the fact that I had to deliver this discourse which led me to investigate the question anew, and therefore I felt bound to tell you the results we have at present attained. Had it not been for this, I should not have published them as yet. We have several improvements of the apparatus in view. We do not pretend to have covered the field. I do not, therefore, wish to generalise. My object has been to refute hasty generalisations. I am content if I have convinced you, as I have convinced myself, that Helmholtz was correct in stating that the siren produces objective tones, whose frequencies are equal to the sum and difference of their primaries, and that the methods we have employed have brought to light no facts opposed to his view that these notes cannot be explained as secondary effects of partials, but as phenomena of the first order—in other words, as real combination tones.

But brief space now remains to discuss the vast remainder of his work, and as I have already published an appreciation of that (*Fortnightly Review*, November 1894), I must content myself with trying to give you, in a few sentences, some idea of the range of his intellect.

His investigations on optics were not less important than those on sound. He invented the ophthalmoscope, by which the oculist can study the inmost recesses of the eye. The theory of colour vision, the theory of binocular vision, the curious subjective effects which are produced when we deliberately deceive our own senses by the stereoscope; these subjects he made especially his own.

In the field of mathematics he was the first to define the peculiar rotatory motion of a liquid known as vortex-motion. Great men had laid the foundations of hydrodynamics before him, but all had overlooked the importance and laws of the vortex. Since the memoir of Helmholtz was published the subject has been widely studied. Lord Kelvin has originated the famous vortex-ring theory of matter; Prof. Fitzgerald has suggested that the ether may be a complex of vortices, or, as it has been called, a vortex-sponge.

On electricity he wrote much—on the theory of the galvanic cell, on electrolysis, on electromagnetism.

In England, at all events, we give the preference, as regards the last subject, to the theory and writings of our own Maxwell.

A lecture, or rather many lectures, might be delivered on each of these topics, but I prefer to devote the few minutes that remain to other subjects.

As I have already said, von Helmholtz, in an age of specialists, was a universal genius. His intellect could light on nothing which it did not illuminate. Hence his opinions on side issues are of more than ordinary importance, his "obiter dicta" are worth attention, his popular lectures acquire a special interest. Let us for a few moments turn to these.

The watchword of Helmholtz in dealing with educational problems is "freedom." Freedom for the student, freedom for the teacher.

In England we are fond of insisting that there are certain things which everybody who aspires to academic rank must know; of hedging in our students by prescribed courses of study. We make them feel that general culture is an iron-bound safe, which they must wrench open before they can attain the gem of real knowledge, rather than a setting, without which the most profound acquirements seem unattractive and dull. Yet von Helmholtz, one of the most highly educated men, one of the most comprehensive geniuses of the latter end of the century, will have no set courses, except as a preparation for a definite profession, is proved that Germany has "retained the old conception of students, as that of young men responsible to themselves, striving after science of their own free will, to whom it is left to arrange their own plan of studies as they think best." Not content with having made the attainment of this ideal almost impossible for English students, doctrinaire educationalists are now beginning to throw their net around the teacher. It is claimed that as the student must go through a prescribed course of study in order to learn, so the teacher must be drilled and examined before he is allowed to teach. Whatever can be said for this plan as regards the less advanced class of teachers, who are to devote themselves to the instruction of children—and in this case I believe there is something to be said for it—it is quite opposed to von Helmholtz's view of what is best when the teaching is of university rank, and the students are men and women. Make it easy for whoever has given some proof of knowledge, and wants to teach, to try his hand; make it easy for the student to go to the teacher from whom he gains the most. Look for the best educational results, not necessarily from the best lecturer, but from the man who is in closest contact with his subject. Do not force your teacher on his audience, but do all you can to establish a bond of sympathy between them. Trust, in a word, to the free play of living forces, and not to the hampering restrictions of "necessary subjects" and "compulsory lectures." This is a paraphrase of the views which Helmholtz held, and he illustrated them by the history of this Institution itself.

"I have often," he said, "wondered that the Royal Institution of London, a private society, which provides for its members and others short courses of lectures on the progress of natural science, should have been able to retain permanently the services of men of such scientific importance as Humphry Davy and Faraday. It was no question of great emoluments; these men were manifestly attracted by a select public, consisting of men and women of independent mental culture." And then he goes on to show that in a German university the teacher is attracted to his work, because he has to deal with a body of students, who are capable of forming opinions, and of judging what is best for themselves.

And this leads us to another point. Von Helmholtz insisted that it is useless and dangerous to crowd the universities with students, who are not capable of taking advantage of the opportunities they offer. "The majority of students," he says, "must come to us with a sufficiently logically trained judgment, with a sufficient habit of mental exertion, with a taste sufficiently developed on the best models to be able to discriminate truth from the bubbling appearance of truth. . . . It would be very dangerous for the universities if large numbers of students frequented them, who were less developed in [these] respects. The general self-respect of the students must not be allowed to sink. If that were the case, the dangers of academic freedom would choke its blessings. It must, therefore, not be looked upon as pedantry, or arrogance, if the universities are scrupulous in the admission of students of a different style of education. It would be still more dangerous if, for any extraneous reasons, teachers were introduced into the faculty, who have not the complete qualifications of an independent academical teacher." ("Popular Lectures," vol. ii. 1881, p. 264-5.)

It would be out of place on this occasion to attempt to apply these views to existing circumstances in London; but with the knowledge that the final constitution of a Teaching University for the metropolis may be decided within the next few months, I cannot but feel that London will be happy if it escapes from the fetters which some of its so-called friends are forging for learning; and if, on the other hand, the wise determination of the Gresham Commissioners to include in the university only institutions of university rank, can be maintained against the attacks which will be made upon it.

Lastly, I wish to defend the memory of von Helmholtz from a possible misconception. Those who cultivate art may perhaps look upon him as the poet or the master of style look upon the grammarian, as a mere gerund-grinder, occupied with the study of the dead materials which they alone can use. Of course Helmholtz was not a great artist in the sense that he was a great scientific man, but it would be most unfair to picture him as interested only in the study of laws, and as insensitive to beauty, as occupied with sound and light, but careless as to music and painting. I could quote passage after passage from his works to prove his keen sense of the loveliness as well as of the order of nature, to show the homage that he paid, and the freedom he accorded to art. His object was not to lead art captive to science; but rather to unite them in an alliance of mutual confidence and support.

"The horizons of physics, philosophy, and art have," he said, "been too widely separated, and, as a consequence, the language, the methods, and the aims of any one of these studies presents a certain amount of difficulty for the student of any other of them." To smooth away these difficulties, to bridge over the separating gulf, to supply the common language, were the objects of the life-work of von Helmholtz. It was a noble ideal, nobly pursued, and crowned with as much success as could reward the efforts of one man. It is an ideal akin to that which dominates this Institution, where science, literature, and art are all heard in turns.

If it is possible to sum up in a sentence the teaching of von Helmholtz, and the work of his life, it is that, in spite of the apparent diversities between science and science, between science, philosophy, and art, there is a fundamental unity, and that the future is for those who detect, amid the seeming discords of the schools, the true harmony which underlies and dominates them all.

ELECTRIFICATION OF AIR AND OTHER GASES.[1]

§ 1. At the meeting of the British Association in Oxford in August 1894, a communication was given to Section A, entitled "Preliminary Experiments to find if Subtraction of Water from Air Electrifies it." These experiments were performed during July of 1894, and were a continuation of experiments which were commenced in the Physical Laboratory of the University of Glasgow in December of 1868 with the same object, but which were then, for various reasons, discontinued before any decisive result had been obtained.

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[1] A Paper by Lord Kelvin, P.R.S., Magnus Maclean, and Alexander Galt, read at the Royal Society on February 21.